

The goal of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce the number and severity of large truck-involved crashes through more commercial motor vehicle and operator inspections and compliance reviews, stronger enforcement measures against violators, expedited completion of rulemaking proceedings, scientifically sound research, and effective CDL testing, recordkeeping, and sanctions. The Office of Research and Technology manages research and technology development and deployment programs for the FMCSA.

The FMCSA R&T activities encompass a range of issues and disciplines relating to motor carrier safety, including problem assessment; policy, safety management, and outreach; drivers; truck and bus vehicle safety performance; and compliance, enforcement and operations.

*Driver alertness and fatigue* primarily supports current and future hours-of-service rule-making activities, along with fatigue outreach and fatigue management technology development.



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## FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION

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# Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance—Part 2

## Introduction

The Federal Motor Carrier Safety Administration (formerly the Office of Motor Carriers, Federal Highway Administration) sponsored a study to gather and analyze data on commercial motor vehicle driver rest and recovery cycles, effects of partial sleep deprivation, and prediction of subsequent performance. The work was carried out in cooperation with the Federal Railroad Administration, and Federal Aviation Administration, by the Walter Reed Army Institute of Research at the General Clinical Research Center/Johns Hopkins Bayview Medical Center. The study began in July 1994 and was completed in May 2000.

Parts 1 and 2 of this tech brief summarize the study final report, *Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance* (Report DOT-MC-00-133). The report will be available from the National Technical Information Service.

Part 1 of this tech brief describes the study background, purpose, and the methodology and results from the field portion of the study. Part 2 describes the methodology and results from the laboratory portion of the study as well as the overall results, applications, and need for additional research.

## Laboratory Study: The Sleep Dose/Response Study

The cause-effect relationship between sleepiness and impaired performance is well established, but the relationship has not been quantified parametrically. This is a necessary step toward determining, for example, how much sleep is necessary to perform subsequent daytime tasks with nominal efficiency and safety. Therefore, the primary objectives of the study were to (1) determine the effects of four sleep/wake schedules on alertness and performance, and (2) develop an algorithmic model to predict performance on the basis of prior sleep parameters.

## Subjects

Sixty-six subjects participated: 16 females, (ages 24-55, mean and median age = 43); and 50 males (ages 24-62, mean = 37, median = 35). All subjects held a valid commercial driver's license but they differed in terms of years of experience and the types of trucks or buses driven.

## Design

The subjects spent 14.5 days in the laboratory: 3 days of training/baseline performance with 8 hours time in bed (TIB) each night; followed by 7 consecutive days of performance testing during which subjects were allowed either 3, 5, 7, or 9 hours TIB each night. This was followed by a 4-day recovery period during which performance testing was continued and subjects again obtained 8 hours TIB each night. Wake-up time was held constant at 0700 hours across all conditions to minimize disruption of circadian rhythms. All performance tests and physiological measures were conducted at the same times of day across all phases of the study.



## Measures

A wide variety of measures were utilized including psychomotor tasks (e.g., various tasks from the Walter Reed Performance Assessment Battery, Systems Technology, Inc. Simulator (STISIM) driving simulator, Psychomotor Vigilance Task (PVT)) and physiological measures (e.g., oculomotor measures from the Fitness Impairment Tester device, vital signs, and a sleep latency test).

Sleep/wake state was measured and recorded 24 hours per day with portable EEG recorders.

## Data Analysis

Data were generally analyzed using a 3-way mixed Analysis of Variance (ANOVA) for the TIB group (3, 5, 7, or 9 hours/night), day (11 days; Baseline 1- Recovery 3), and time of day, with repeated measures on the latter two factors. The number of levels for the time-of-day factor depended upon the daily sampling rate for a given task (for example, 4 levels for STISIM, which was administered at 0730, 1030, 1330, 1930 hours). Main effects for sleep group, day, and time of day, as well as their interactions, were analyzed. The interaction of TIB Group X Day, if significant, was further analyzed using simple main effects ANOVAs. Greenhouse-Geisser corrections were applied to all repeated-measures tests. Post-hoc comparisons among means were conducted using the Tukey HSD test. Results were deemed significant at  $p < .05$ .

## Results and Discussion

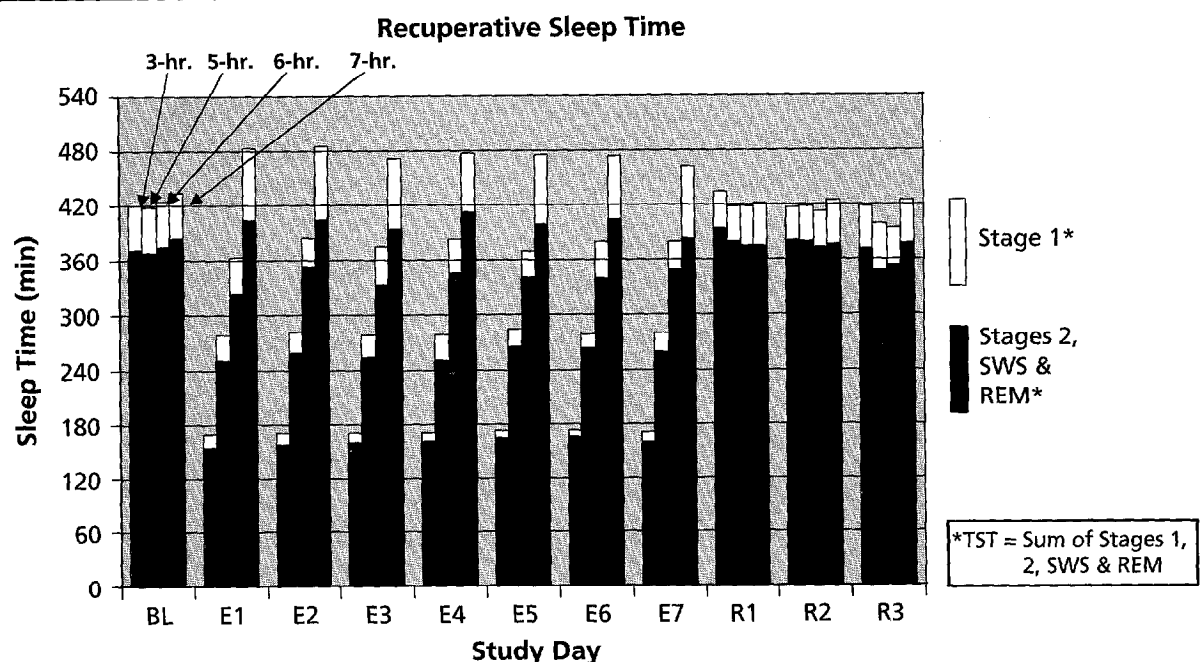
In the laboratory study, the 3, 5, 7, and 9-hour TIB groups averaged 2.87, 4.66, 6.28, and 7.93 hours of sleep, respectively, across the 7 days. (See Figure 1) Group-related (i.e., sleep dose-dependent) differences in subsequent daytime performance were evident (and quantifiable) for several measures.

Even a relatively small reduction in average nighttime sleep duration (i.e., to 6.28 hours of sleep—the average amount of sleep obtained by the 7-hr group) resulted in measurably decremented performance — e.g., on the PVT. This decrement was maintained across the entire 7 consecutive days of sleep restriction. (See Figures 2 and 3.) This suggests that there was no compensatory or adaptive response to even this mild degree of sleep loss.

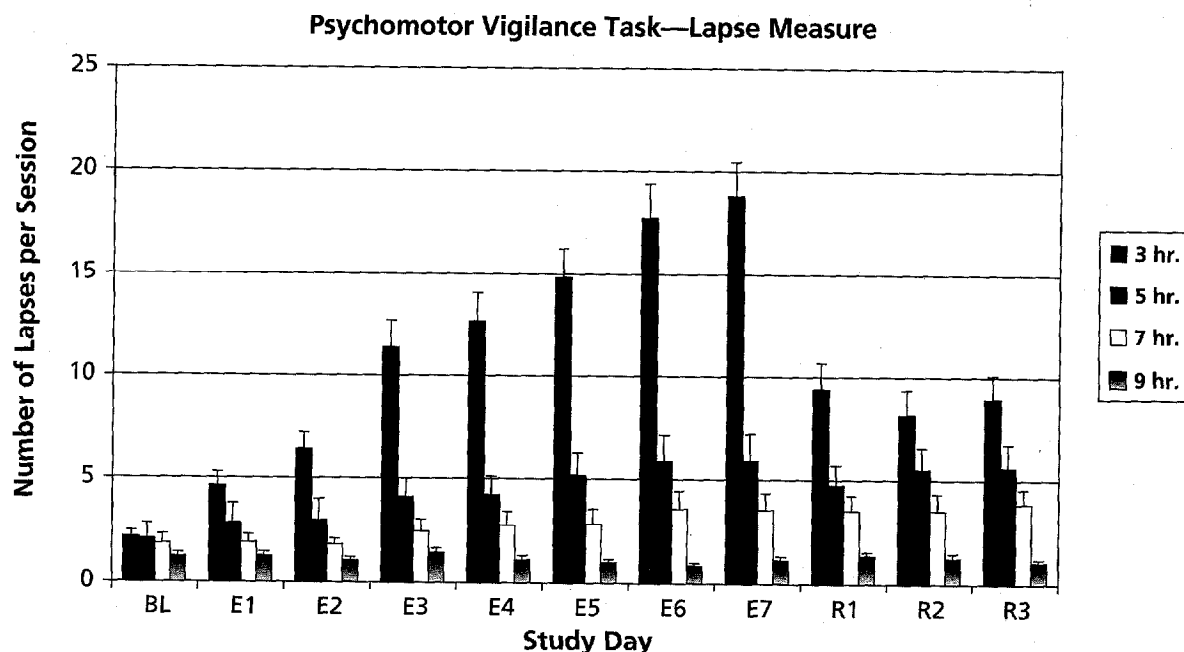
Following more severe sleep restriction—e.g., the 3-hr group—recovery of performance was not complete after 3 consecutive nights of recovery sleep, with 8 hours spent in bed on each night. Thus, full recovery from substantial sleep debt may require extended recovery sleep. It also suggests that daytime alertness and performance capacity is a function not only of an individual's circadian rhythm, time since the last sleep period, and duration of the last sleep period, but is also a function of his/her sleep history, extending back for at least several days.

**Figure 1.**

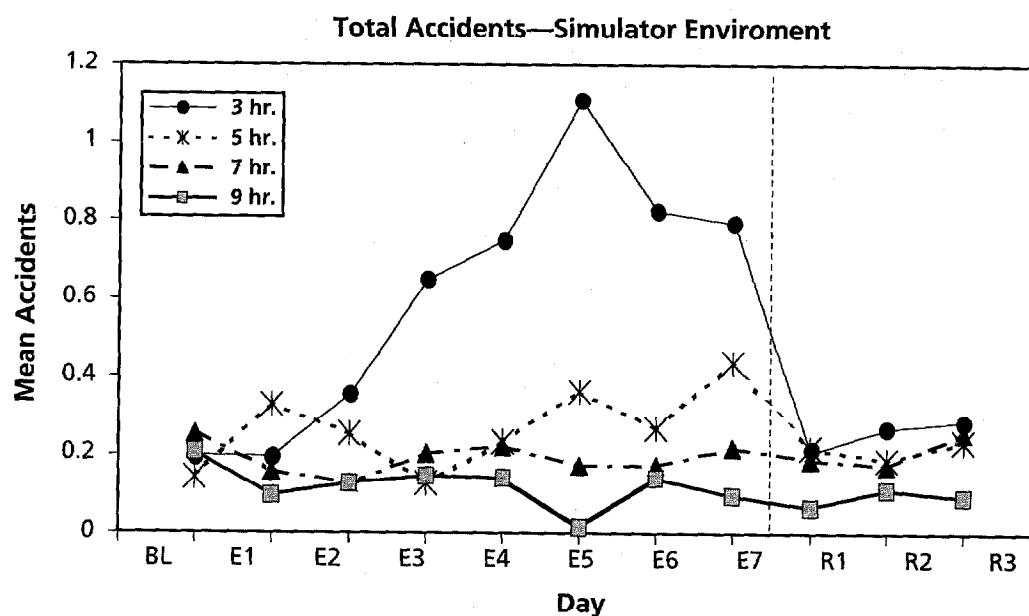
Mean recuperative sleep time in minutes (sum of stages 2, SWS and REM) with stage 1 amounts in minutes separately for each sleep group across study days. Recuperative sleep time plus stage 1 equals total sleep time.



**Figure 2.**  
 Mean number of responses-times greater than 0.5 s, on the psychomotor vigilance task across study days by sleep group.



**Figure 3.**  
 Mean number of accidents per 45-minute simulation, across study days by sleep group.



The temporal relationship between EEG-defined lapses in alertness and accidents on a simulated driving task was low. This indicates sleepiness-induced performance decrements most often occur without visually-observed electrophysiological evidence of

impaired alertness.

Of the various performance measures used, the Psychomotor Vigilance Task (PVT) was deemed optimal. This was because:

### Researcher

This study was performed by the Division of Neuropsychiatry, Walter Reed Army Institute of Research, 503 Robert Grant Avenue, Silver Spring, MD 20910; and General Clinical Research Center/Johns Hopkins Bayview Medical Center. Contract No. DTFH61-94-Y-00090

### Distribution

This Tech Brief is being distributed according to a standard distribution. Direct distribution is being made to the Service Centers and Divisions.

### Availability

The study final report (DOT-MC-00-133) will be available from the National Technical Information Service, Telephone: (703) 605-6000

### Key Words

Sleep restriction, CMV drivers, driving simulator, performance, actigraphy, sleep/ performance model

### Notice

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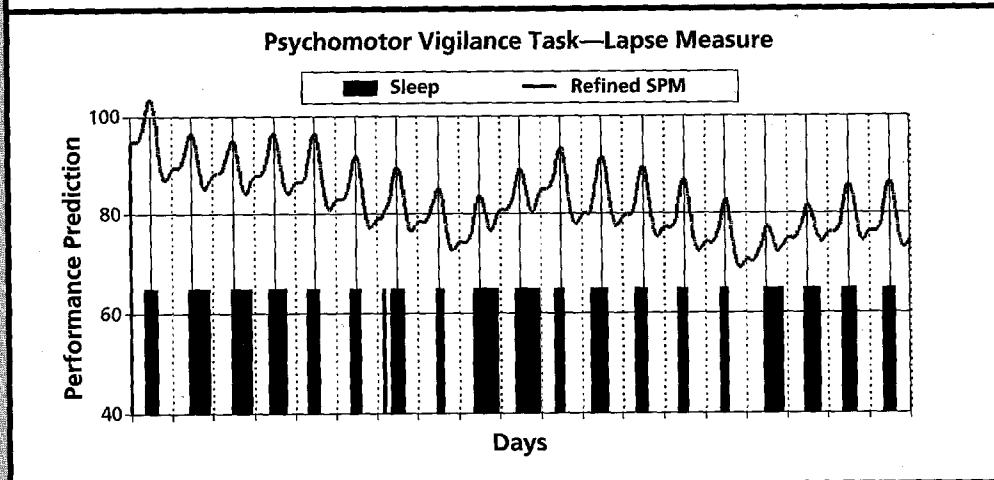
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**Figure 4.**

**SPM predicted performance based on actigraphically recorded sleep per 24-hour period for short-haul driver H7076 (ranked high on daily variability in total sleep time relative to the other short-haul drivers studied). Actigraphically recorded sleep is indicated by black bars (height is arbitrary; width = length of sleep bout). Solid vertical lines indicated 0000 hours (midnight).**



- there were no apparent learning effects with this measure during the experimental phase of the study;
- the measure was sensitive to the experimental manipulation (i.e., there was adequate separation in mean performance levels between the various sleep groups); and
- although fatigue might affect PVT performance, and account for some of its sensitivity to sleep loss, it is a short-duration task (10 minutes)—thus fatigue would be expected to account for a relatively small portion of the variance.

### Results, Applications and Need for Additional Research

Results from the field study show that daily sleep duration is correlated with duration of off-duty time. Both long- and short-haul drivers averaged approximately 7 1/2 hours of sleep per night, within normal limits for adults. However, there was significant day-to-day variability in sleep duration in both groups, with long-haul drivers obtaining almost half of their daily sleep during work shift hours—from which it can be inferred that they spend a significant portion of their on-duty hours with a significant sleep debt. Therefore, in addition to optimizing work/rest schedules, investigation of other means for improving driver performance and alertness is advisable.

There appear to be prospects for augmenting on-line measures of performance in operational environments with tools such as the Sleep Performance Model. (See Figure 4) This would allow better-informed decision-making regarding the likelihood of impending performance failure or the need for using countermeasures on an individual basis. The model could potentially be enhanced to accept performance data feedback so that the model parameters could be optimized to the individual on an ongoing basis. This might be a subject for additional research.

### Reference

Balkin, T., Thome, D., Sing, H., Thomas, M., Redmond, D., Wesensten, N., Williams, J., Hall S., Belenky, G. *Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance*. FMCSA Report No. DOT-MC-00-133, May 2000.